Design and Performance of Ball Milling for Powder Metallurgy Composites

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***Abstract*:- The composites playing a vital role in the present world in the field of material science with their enhanced properties compared to base materials. One of the efficient way of preparing composites is through powder metallurgy technique. This technique mainly requires proper mixing of powders, followed by compaction and sintering. Among them, the main and initial step is mixing of powders in a proper manner. Therefore, the present work concentrates on mixing of two available powders with a proper proportion in a ball mill by fabricating it, compacting the powder mixture in hydraulic pressing unit with a suitable die and conducting SEM analysis on the fabricated sample followed by hardness test on the green samples. The major advantages of this machine include lower floor space; low initial cost also the quantity of powder required for testing is usually less. So the above mentioned machine can be used effectively. It is therefore recommended that this mill can be developed for both research and industrial uses.**

Keywords—Composite,MMC,Powder metallurgy,SEM

I. INTRODUCTION

The composite material is the combination of two or more materials with significantly different physical or has chemical properties that are when combined, produces a single material which has enhanced properties when compared to individual constituents. These materials are generally classified based on matrix and reinforcements. Based on matrix it is classified as Metal matrix composite, ceramic matrix composite, Polymer matrix composite. Whereas based on the reinforcement it is classified as particulate reinforced, Fiber reinforced composites etc. Based on the application and suitability the required type of composites is used. The present aerospace, automobile kind of field requires materials with less weight and comparatively good strength[1]. These requirements can be easily achieved by utilizing composite materials at different parts. Most of the parts of above mentioned fields use metal matrix composites (MMC)[2]. The MMC are mainly prepared by two routes, namely Powder metallurgy and Casting method. The powder metallurgy route mainly consists of three stages, Mixing of the powders, compaction and sintering. The mixing can be achieved by many methods and one of such method is by utilizing ball milling equipment. The ball mill equipment consists of hollow cylinder filled with powders to be mixed and number of balls. This cylinder arrangement will be rotated at required speed for pre-determined time. There are various kind of ball milling equipment's which are classified based on its axis of rotation(Attrition mill, Horizontal mill), type of motion (1D vibratory mill, planetary mill, 3D Vibratory mill)[3]. These the ball mills are used in mineral industries where along with grinding process it is also used for cold welding as well, with the purpose of producing alloy from powders[4].The mixing of powders can be compacted in a suitable hydraulic pressing unit. The specimens after the process of compaction are called as green specimen [5]. The strength of any specimen prepared with powder metallurgy route mainly depends upon proper mixing of powders that can be observed by using available electron microscopes such as SEM (Scanning electron microscope)[6]. TEM (Transmission Electron Microscope).

II. OBJECTIVES

Ball mill equipment places an important role for the conversion of raw materials into fine powder form and also used for mixing a matrix and reinforcement in powder form[7].The present study mainly concentrates on the latter part. The objectives of the present work includes, to study different available ball milling machines and fabricate the mini ball milling equipment , followed by testing the prepared model.

III. MATERIALS

In order to fabricate mini ball milling machine which can be used for laboratory purpose the following materials are considered and function of each are as described below.

A. Gear Motor

This is an electric motors which is used to get alter the speed and torque values. This generally consists of Motor and gear arrangement system; it is also called as gear reducer or gear box. For the present study gear motor of 60 Watts is used which is having operating voltage of 12V.

B. Belt Drive

The belt drives are the one of the efficient power transmitting devices. The belt drives are mainly classified based on the type of the belt utilized in the work. The present work utilizes toothed belt drive. The advantages of using such belts is that

it these transmits the power with higher accuracy than the flat belt.

C. Bearings

These are the machine elements which help for reducing friction between the moving parts. Among all the available bearings, a pillow block, also known as a Plummer block or bearing housing is used for the present study. This is a pedestal used to provide support for a rotating shaft with the help of compatible bearings & various accessories

D. Voil

The main component of ball milling equipment is voil, which is hollow cylinder with certain thickness, in which raw materials or powders are filled and closed with a lid. Then this setup is allowed to rotate at a pre determined speed and time. For the present study hollow cylinder of inner diameter 70 mm, outer diameter of 86 mm is used.

E. Powders

The ball milling is generally used in conversion of raw materials into fine powder form and used for mixing a matrix and reinforcement in powder form. Since the present work concentrates on latter one, The Aluminum is used as matrix material and alumina (Al_2O_3) is used as reinforcement. The combination includes several applications in the field of automobile and aircraft parts [8].

IV. DESIGN CALCULATION

The Main objective of the present work involves the fabrication of mini ball milling machine which can be effectively used for mixing purpose, hence the following necessary design calculations are done by considering aluminum powder as a base material and aluminum oxide as reinforcing material.

Density of aluminum = 2700kg/m^3
Density of Al_2O_3 = 3950 kg/m^3
Density of stainless steel ball = 7850kg/m^3
Total mass of powder = Mass of aluminum (M_A) + Mass of Al_2O_3 (M_{Al2O3}).
Volume is the ratio of mass by density of the material.
For 100gm of powder specimen preparation and by considering maximum 3.wt% of reinforcement material.
Volume of aluminum= mass/density=3.70x10^{-5} m^3
Volume of Aluminum Oxide=7.59x10^{-7} m^3
The mass of the balls used in the ball milling jar is generally 10 to 15 times the mass of powders are used[9].
Therefore by considering 10 times the mass of powders used the volume of ball will be 1.31x10^{-4} m^3
Therefore the total volume will be = 1.68x$10^{-4}$$m^3$
The volume of hollow portion of cylinder should be 2 times the volume of materials used therefore, volume of voil= 3.3759x10^{-4} m^3
The required diameter of the voil is,
Volume of voil= $(\pi/4)xD_i$ x1.25 D_i
Based on which the internal diameter of the voil is found to be
D_i = 70mm.
Motor Specification includes Operating Wattage = 60 W
Input Voltage = 12 V
Belt Drive Specification includes
Large pulley diameter, D = 150 mm
Small pulley diameter, d =70 mm
Center distance, C = 180 mm
Motor speed, N2= 35 rpm
Using the speed ratio, calculate the Cylinder speed N1
Speed ratio=(D/d)=(N1/N2)=2.14 results in N1=75 RPM
Length of the belt, $L=2C+(\pi/2)(D+d)+((D-d)x2)/4C$
L=714mm.

V. FABRICATION AND TESTING

A. Powder Metaullergy

The powder metallurgy is a process of forming, in which Heating of the compacted metal powders takes place below the melting point.The particle size, shape and size distribution of metal powder affect the characteristics and properties of the compacted product. The process mainly involves three steps namely blending, compacting and sintering[10]. Sinceall metals can be produced in powder form but not all have the desired properties which are necessary for economical production hence the different powders are blended. The blending of different powders depends on the application where the fabricated material is supposed to be used. After blending process, the powders are compacted in a die of required shape using suitable pressure. The compacted powders after this process are called as green samples, the properties of these samples are can be still enhanced by sintering process, where the green samples are heated to a temperature just below its melting point so that suitable bonding and strength can be achieved. The present work involves the preparation of samples up to the stage of compaction (green samples) and followed by testing in SEM.[11]

B. Specimen preparation and testing

The model for the present work is prepared with the help of all above mentioned materials. The fabricated model is as shown in figure 1. The motor is connected to the cylinder with the help of belt arrangement. The speed of the cylinder can be controlled by separate connections, the milling setup is allowed to run for predetermined time and speed after adding milling balls and different powders which are supposed to mixed as shown in figure 2. The aluminum and alumina are mixed at 0wt.%,1wt.%,2 wt% and 3wt.% for a total weight of 20gm of the mixture. The mixed powder is poured into a die and allowed for compaction at a suitable pressure. The image of the compacted specimen is as shown in figure 3.

The specimen after compaction is called as green sample. The prepared specimen is allowed to test in order to find the suitability of the fabricated mini ball milling machine. Since the main objective is to mix the powders in a equally distributive manner, The compacted green samples are tested in scanning electron microscope (SEM) for understanding micro graphical arrangement.

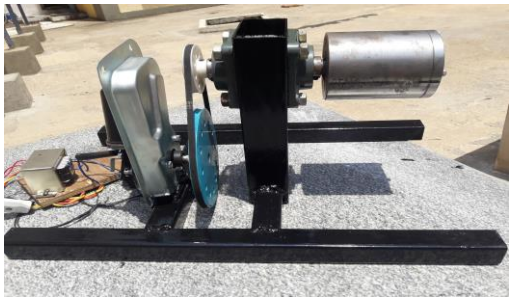

Figure1. Fabricated model

Figure 2. Mixing of powders

Figure 3. Compacted specimen

VI. RESULT AND DISCUSSION

The Scanning electron (SEM) images of the compacted green samples are as shown in figure 4 and some more images of SEM for different weight percentages are as shown in figure 5.

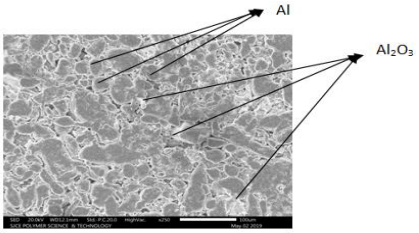

Figure 4. SEM images of green sample specimen

Based on the SEM images of the green compacted specimen of aluminum and alumina for different weight percentages it is observed that, distribution of alumina in the aluminum matrix is found be appreciable.

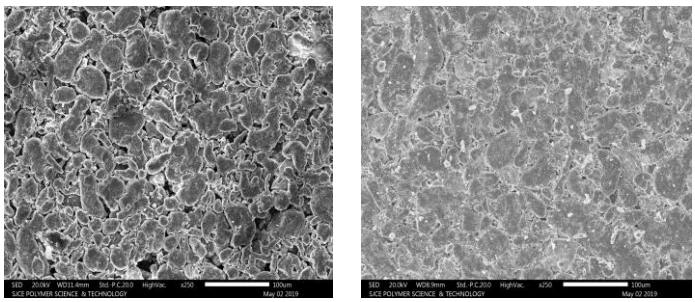

Figure 5.SEM images of green sample specimen for different weight percentages

VII. CONCLUSION

The design of the laboratory purpose mini ball mill was successfully carried out and fabricated for powder metallurgy route composites. The performance test on the fabricated ball mill for the aluminum in powder form and blended with alumina shown proper distribution through scanning electron microscope images for different weight percentages of alumina. The ball mill is used for different speed, time conditions and conditions with the capacity of 250gms can be operated.

REFERENCES

[1] Mina Bastwros, Gap-Yong Kim, Can Zhu, Kun Zhang, Shiren Wang, Xiaoduan Tang, Xinwei Wang,"Effect of ball milling on grapheme reinforced Al6061 composite fabricated by semi solid sintering",Composites Part B 60,pp.111-118,2014.

[2] Rohit Sharma, Saurabh Jha P, Khushboo Kakkar, Kushal Kamboj, Pardeep Sharma,"A Review of the Aluminium Metal Matrix Composite and its Properties". Volume: 04 Issue: 02, Feb -2017

[3] Thakur Prasad Yadav, Ram Manohar Yadav, Dinesh Pratap Singh,"Mechanical Milling:a Top down approach for the synthesis of Nanomaterial and Nanocomposites"Nanoscience and Nanotechnology,pp.22-48,2012.

[4] P. Jagadeesh, M.Yuvaraj, M.Yuvaraj, R.Yuvaraj, S.Sasikumar, "Fabrication of low cost ball milling machine",ISSN:2454,vol.1,Issue 1,2016.

[5] F F Kamaruzaman, D M Nuruzzaman, N M Ismail, Z Hamedon, A K M A Iqbal, A Azhari,"Microstructur and properties of Aluminiun-aluminium oxide graded composite materials",2017.

[6] Mehdi Rahimian, Nader Parvin, Naser Ehsani,"The effect of production parameters on microstructure and wear resistance of powder metallurgy Al-Al_2O_3 composite",Material and Design 32,pp.1031-1038,2011.

[7] L Girisha,Dr. Raji George, Pradeep Kumar Ilay, "Investigation of Damping Behavior of Aluminum Based Hybrid Nanocomposites", International Journal of Engineering Research & Technology (IJERT), Vol 3 issue 9,2014.

[8] K. John Joshua, P. Sherjin, J. Perinba Selvin Raj, "Analysis of Ball Milled Aluminium Alloy 7068 Metal Powders"Volume 4 Issue 8 August 2017.

[9] Shubham Krishna Mhetar, Akshay Ashok Nerle, Rohit Laxman Patil, Rahul Ankush Pawar, Mayur Manik Patil, Hemant Tanaji Shinde,"Cost effective ball milling machine for producing nanopowder",vol.4,Issue 4,Apr 2017.

[10] Dewan Muhammad Nuruzzaman,Siti Nur Sakinah Jamaludin,Farah Fazira Binti Kamaruzaman, Shahnor Basri, Nur Amir Mardiana Binti Zulkifli,"Fabrication and mechanical properties of Aluminium-Aluminium Oxide metal matrix composites",vol.15,pp.68-75,2015.

[11] F F Kamaruzaman, D M Nuruzzaman, N M Ismail, Z Hamedon, A K M A, Iqbaland A Azhari, "Microstructre and properties of aluminum-aluminium oxide graded composite graded materials".2017.